COMMERCIAL SPACE TRAVEL AND SPACE TOURISM

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Abstract

This paper presents a concept of a Space Travel Plan comprising of commercial and tourism segments. So far Space travel has been restricted only to the Astronauts selected by the respective Space Agencies. After the Apollo Moon landings, NASA turned its focus to the Space Shuttle program projecting the idea of low cost access to Space. This led a generation of Apollo enthusiasts to believe that Space tourism would come to be established within the reach of the general public although at a cost. The Soyuz-Apollo missions, MIR Space station and the Freedom International Space station all seemed to strengthen the idea that Space tourism and commercial Space travel would be realised by the turn of the last century.

Till now commercial utilisation of Space has continued to be the main agenda of most of the space-faring nations. For commercial Space travel and tourism to come down to the level of economic feasibility, new approaches to technological innovations are needed. Reusable Launch vehicles are the key elements in the realisation plan. At present, fully reusable launch vehicles are in the design stage.

Although the Space Shuttle is an incredible machine, it is complex, labour-intensive, very expensive, partly only reusable, and has a less perfect safety record. With the decision of NASA to end the shuttle program, low cost access to space can be the next big thrust program.

With the current status of technological development it is possible to design and develop space planes which can take-off and make a perfect return from orbit on auto pilot only, whether it is night or day and regardless of weather conditions. Future space planes should promise dramatic increases in space flight safety levels for launch, re-entry, and landing. The technology and challenge will be to combine the relative simplicity of expendable rockets with the reliability and safety of airplanes, to end up with a safe, economic launch vehicle.

Developing a passenger space travel analogous to air travel has a great potential from economical, social and international-relations points of view. Passenger Space travel can start by augmenting and innovating already existing technology. It is likely to grow into the largest commercial activity in space. Space tourism can no longer be treated as fiction but as the next logical step in evolution of spaceflight. Addressing all the inherent risks in space travel is one of the daunting tasks but as usual human civilisation can march along by doing the seemingly impossible.

The paper explains the different issues that need to be addressed in the various phases of such a mission. Although extensive space tourism market studies are surely needed to make reliable forecasts and estimates, and to attract investors, it is expected that the space tourism business could grow to be an economically very important sector.

Keywords: Space Planes, Reusable Launch Vehicles, expandable launch vehicles, Space tourism

1.INTRODUCTION:

"It is difficult to say what is impossible. Yesterday's dream is today's hope and tomorrow's reality"- Robert Goddard

Throughout human history there has always been a strong drive to explore and travel to new and exciting places. The exploration of the cosmos has been in the imagination of humanity since mankind first looked at the night sky. Since the beginning of space age, possibility of space flights within the reach of general public has been one of the undeclared agenda for space-faring nations.

Space travel is the next logic step for tourists. Space tourism is aimed at providing services for humans to access and experience space for adventure and recreation. A space tourist would be a person who travels to and experiences space for adventure and recreational activities specific to outer space. This definition excludes communities of Astronauts who journey to outer space for professional activities.

The United Nations World Tourism Organization (UNWTO) defines tourists as people who "travel to and stay in places outside their usual environment for more than twenty-four hours and not more than one consecutive year for leisure, business and other purposes not related to the exercise of an activity remunerated from within the place visited". Considering the rigours of space travel, these figures may be appropriately modified to a nominal duration from 15 minutes to 7 days depending on whether it is suborbital or orbital flight.

2. SPACE TOURISM

Space tourism as an evolutionary process has already started with the first non-professional astronaut paying for a trip to outer space. Mr. Denis Tito became the first private space tourist when, in 2001, he travelled to space as a fare paying tourist. Although the flight involved a government vehicle, his participation in it was privately funded. Further progress in space tourism depends very much on various technical issues like re-usable technology and other related developments which are specific requirements for space tourism.

Space related tourism is today restricted to adventures and recreation opportunities that are related to space but remain terrestrial. Such terrestrial-based opportunities help to increase the

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market potential for actual space tourism by making the client crave for the real space tourism experience. Adventure tourism is a large and growing market. It may be the branching arm into space tourism related activities. With current market trends it is clear that there is a huge potential market for space tourism.

The **space tourism market** will evolve through different phases, starting with adventure tourists exploring space travel by paying several million dollars for a space journey and stabilising into a well developed tourist market with lower prices and easy accessibility. Current market surveys indicate that on an average 80% of people between ages of 20 and 29 are interested in space travel [1]. Several industry competitors are aiming for this market by providing Earth-based space related tourism activities. One of the biggest strengths of the emerging space tourism is the strong economic rational with government and private sector support.

The tourism industry represents 10% of the world economy [2]. It is an industry capable of pushing governments and private entities into building a cost effective reusable launch vehicle, which will give better means for further human space exploration.

Government input could help private investors narrow this gap and establish niche markets. This is truly needed since the high investment cost and the long term payback period are discouraging private initiatives.

3. SPACE TRANSPORTATION

Space transportation is still an expensive industry. Only the USA-Space Shuttle and Russian-Soyuz capsule can carry humans into space today at higher-end cost of about US $20,000 per kg [2]. Efforts to expand range of human travel-rated vehicle have not succeeded till today. Projects like Hermes, Hope-X, and Buran shuttles are still under various stages of design and development. Various engineering limitations related to propulsion, high-temperature withstanding structures etc. will have to be overcome before a commercially viable space vehicle is realised leading to a drop in the price of the transportation. Technology developments must also take environmental aspects such as noise pollution, space debris production and deep impact into account.

In USA, NASA is planning to have its true **second generation** of reusable launchers operational around 2020. With a goal to limit the cost per launch to around $6000 per kg payload , much less than the current $20,000 per kg [2] to LEO; but still far too expensive for a viable space tourism industry. New Launch Vehicle is also to be 20 times safer than Shuttle. Space Shuttle's current statistic is 1 in 250 chance of a catastrophic failure [2].

The **third generation** space vehicles are expected to come into use around 2025[2]. Although flights with the third generation launch vehicles will be quite expensive, the prices could be low enough to make flights possible for the first adventurous individuals with an average income that provides for saving some months or a year of their salary for their dream flight.

Access to space for less than $50 per kg, and with it the possibility for mass space tourism, is hoped to arrive with the **fourth generation** of reusable launchers, and envisioned to be operational around 2040 [2]. This generation of vehicles are envisioned to be airplane like, air-breathing vehicles based on new super light materials, will have efficient rocket engines, and will require no more maintenance than a modern airliner.

In Japan, plans for future crewed spacecraft seriously take into account possibilities and requirements for space tourism. The egg-shaped ***Kankohmaru*** of the Japanese Rocket Society is a study concept for a **fully re-usable** single stage spacecraft [2]. It is a reusable rocket without wings that would take off and land vertically. Specifically designed for space tourism, it would be able to carry 50 passengers into orbit. The vehicle would weigh about 5,50,000 kg at launch, be constructed from mainly lightweight aluminium and composite materials and use 12 rocket engines operating on liquid hydrogen and oxygen[2].

3.1 Present-day technology and challenges

The risk factor in current launch vehicles is quite high compared to Air travel because the design margin for vehicle safety is low. Rocket engines operate at extremely high pressures to generate sufficient thrust, which in turn puts heavy loads on the launcher's structure. And they use large amounts of extremely dangerous, explosive propellants. Therefore safety for the space tourist from Launch vehicle malfunction is of the utmost importance.

Commercial jetliners coming from the factory usually make a few test flights to ensure that its air-worthiness before being handed over to the customer. On similar lines a space-flight worthiness certification is a must for Launch Vehicles.

With the current rocket engine and materials technology, even expendable launchers are heavy and hardly powerful enough to make it into space without discarding parts of them along the way; rocket stages are jettisoned as their propellant tanks run empty. These stages fall in the ocean or crash on the land and cannot be used again. A truly reusable launcher cannot benefit from such a simple staging system, but still must be able to take larger satellites to orbit.

Another problem is that today's rocket engines can only be operated for 10 minutes or so before major maintenance activities or new motors are required. Jet engines, as used in modern airliners, last for month with no technical issues.
A choice has to be made in the following basic questions:

- Free-flying vehicle vs orbital facility
- One vs Two stages
- Rockets vs combination with air-breathing
- Horizontal vs Vertical takeoff/landing

3.2 Reusable Launch Vehicle (RLV) in space transportation:

A truly reusable launcher that is easy to maintain is needed to lower the price of launching passengers and cargo into space. Preferably, the system should involve only one single stage vehicle without expendable tanks or boosters.
The launcher could be designed to have combined rocket/jet engine that can use oxygen in the atmosphere while flying at relatively low altitudes. This would mean less onboard propellant, smaller tanks and, therefore a smaller, lighter vehicle.
Development of Launchers that fit all of the stringent space-travel requirements is of primary importance.
As long as launches are expensive, the number of satellites and people to be launched each year remains small. Reusable launchers only become economical at high launch rates, so their development and operation are not justified for such a limited market. Expendable launchers therefore remain in use, launch cost remain high and, in turn, the satellite market stays small.
Space tourism may help out, as it offers a clear, large market worth billions of dollars per year [2], where success depends on efficient, reusable vehicles that are making numerous flights. Reusable launchers developed for space tourism can reduce launch costs dramatically, enabling not only regular tourist flights but also cheap satellite launches. This would offer an enormous boost for the exploration of the solar system, the colonization of the planets, the construction of space factories and solar power-generating satellites, and other possibilities which many have probably not yet been identified.
Development of Reusable Launch Vehicle (RLV) would be a major drive for space tourism.

3.3 Space Shuttle for space transportation:

The Space Shuttle is an incredible machine. It is the first and only reusable spacecraft, a heavy lift launch vehicle that can also return heavy cargos, a spacecraft that, to date, has delivered three times more people to orbit and brought them back than all other launchers combined, and has the most efficient rocket engines ever produced. However, it is also complex, labour-intensive, very expensive, partly only reusable, and has a less perfect safety record.

3.4 Space Planes- a feasible option for space transportation:

With the current status of technological development it is possible to design and develop space planes which can take-off and make a perfect return from orbit on auto pilot only, whether it is night or day and regardless of weather conditions.

Conceptually a Space plane [2] is three vehicles combined into one. During launch it is a rocket, depending on the thrust of its powerful engines to gain sufficient altitude and to accelerate to the orbital velocity. In space, the space plane is a satellite, kept in orbit by balance between Earth's gravity and the centrifugal force caused by the vehicle's circular movement around the planet. To come back to Earth, the bigger engines are fired opposite to the flight direction, slowing the space plane down so that it falls back into atmosphere.
The vehicle changes into airplane, with its wings creating sufficient lift for a smooth glide back to Earth's surface.
The technology and challenge will be to combine the relative simplicity of expendable rockets with the reliability and safety of airplanes, to end up with a safe, economic launch vehicle.
During step-wise test campaigns similar to those of commercial or military aircraft, space planes could be tested much more thoroughly than ordinary, expandable rockets. They could have higher safety margins and more backup systems, and enable safe aborts during the entire launch phase. The Space Shuttle, with its various abort scenarios, is partly a space plane, but still depends on expendable rocket technology.
Future space planes should promise dramatic increases in space flight safety levels for launch, re-entry, and landing. They should constantly be under full control, be able to come back from space at almost any time (day, night, even in bad weather), need not rely on rescue teams and parachutes for recovery. Moreover, space planes should offer safe abort possibilities during almost all flight phases. Just as airliners are generally safer than balloons, parachutes, and fighter aircraft, true space planes could also improve safety levels for human spaceflight. Advanced space planes should be designed to be just as safe as modern airliners, thus making mass space tourism a possibility.

4. SAFETY MEASURES AND REGULATIONS

In USA, the space planes operated by Orbital Destinations are all subject to the rules of the Federal Aviation Administration (FAA), which certifies the passenger launch vehicles and license companies operating these spacecraft. The FAA regulations for space planes are an extension of those for airplanes and have been established to

ensure the reliability of the vehicles and operators and the safety of the passengers. The FAA is an US government organization, to prevent commercial interests from becoming more important than safety standards. They also supervise the Air and Space Traffic Control during atmospheric flight

The exposure to microgravity is short for suborbital flights so the effects on endovascular, neurovestibular, and musculoskeletal systems are small. Effects of radiation and space motion sickness are also limited due to short term nature of the flight. This means that medical requirements can be nominal and a set of guidelines, rather than selection criteria, can be set up for passengers. Crew medical standards will be based on what exists for commercial airline pilots and astronaut pilots, taking into account maximum radiation exposure limits.

Radiation is everywhere, also on Earth. It not only comes from space but also out of ground. The average dose of radiation picked up on the surface of Earth is about 2.6 milli-Sieverts per year [2]. However, radon gas coming from the ground or out gassed from concrete in new buildings can result in levels that are five times higher. Spacecraft can be shielded from this normal background radiation by dense materials, such as metals but also by water tanks. However, only a limited amount of shielding can be applied otherwise spacecraft would be too heavy to launch

Personnel working in nuclear plants are allowed annual dose of some 10 times higher than the normal exposure on Earth [2]. Using this as a standard for space tourism would result in a maximum total spaceflight duration of 10weeks per year. This should fit with nearly anyone's annual holiday schedule, but for the staff of space tourism operators it would be a severe limitation. Probably space planes pilots and other space tourism workers would be required to rotate between space and earth based jobs, working most of the year on the ground to reduce the radiation effect. Total lifetime radiation dose restrictions may also result in limited orbit career durations. However, during solar flares phenomenon a result in doses of thousands of milli Sieverts, up to 20,000, which can be fatal.

In the past, astronauts had estimated 1 in 250 chance of not surviving a Space Shuttle mission [2]. Although at that time this was "par for the course", a similar reliability figure today would mean one unacceptable Orbital Destinations space plane crash each year. The corresponding figure for Commercial airline passengers is only 1 in 2 million [2]. Therefore, every effort is to be made in both the design and the operation of the space planes to minimize risks and also the insurance costs.

A range of regulations are needed, notably in order to preserve public safety and enable the insurance industry to play its role efficiently. The office of commercial space transportation in the US FAA is already working in this direction, including studying the extension of air traffic control to Earth Orbit and medical guidelines for space travel passengers.

With a total of about 240 human space missions to date, the average fatal accident is 1 per 60 flights. This is extremely high when compared to commercial aviation: taking a plane to go on holidays exposes to only 1 in 2 million probability of not arriving at the destination. Even parachuting is very safe in comparison, with only about one fatal accident per 100,000 jumps [2].

A new type of rocket is usually declared operational after only one or two flights, while typically 1000 test flights are made with one single plane before a new airliner goes to service.

Mass space tourism will probably require a safety level close to that of today's airlines; otherwise the market will be too small. Not many people will be comfortable making a spaceflight that is more dangerous than flying on an airliner. Moreover, the insurance fees would be prohibitively high

5. COMMERCIAL ASPECTS OF SPACE TOURISM

Growing work on the feasibility of developing a passenger space travel industry analogous to air travel shows that it has potentially great economic value; that it would be a very popular service and requires far less investment than space agencies already receive; and that substantially funding for work on this possibility is very desirable from many points of view, economically, socially, politically and internationally.

Surveys performed in Japan, Canada, USA, Germany and England all has a similar pattern, with most people being keen to make a visit to space.

It seems probable that popular space travel services can grow throughout 21st century much as air travel services grew during 20th century. Indeed, in view of the growth and globalization of the world economy and financial system over the past 100 years, it seems possible that while the air travel took about 100 years from its start in 1903 to reach a turnover of $1 trillion/year, space travel might reach that figure within 50 years [3].

In recent years, many small firms have been emphasising that it is much more attractive to start with suborbital space tourism, because:

- The required technology is much less complex
- Ticket costs are much lower
- The up-front investments are more in the range of millions, not billions

As a successful orbital space tourism business, the Space Shuttle would be far too expensive. Assuming that a passenger module for 74 space tourists could be installed in the Cargo bay of the

Orbiter and that 12 flights per year could be made, the ticket price would be around $3.6 million [2]. While there are probably a number of people willing to pay such an amount for a space flight experience, flying 74 of them at the same time would very shortly deplete the limited available market. Moreover, the Shuttle turnaround time of around 3 months would be unacceptable for a large scale space tourism operation.

To start with, **sub-orbital passenger space travel** can start using existing technology. The key to reducing launch costs is not developing new technology but addressing a sufficiently large market.

The key issue for reducing launch costs is not technical but commercial-to target a market which can grow large enough to amortise the vehicle development cost, and to generate sufficiently voluminous operating statistics to achieve acceptable levels of reliability and safety.

In order to realize passenger space travel as soon as possible, collaborations could make most effective use of existing technologies. Space agencies' of expenditures of some $20 billion/year, if invested commercially, could generate revenues growing by some $29 billion/year, earning 10% annual return profits on their investment, or some $2 billion annual profits, and creating of the order of 1 million new jobs/year [3].

The only way in which enormous investment in space technology can start to earn an economic return is through the development of a space tourism industry. Economically, general public space travel and tourism is the most attractive paradigm for post-cold war, 21st century space activities.

It seems that space tourism will grow into **a viable business and a major economical factor** as the limited market surveys done so far indicate that many people are interested in going into space. One survey [2] concluded that about 70 percent of the Japanese want to make such a trip and that most of them are willing to pay at least three months of salary to make a flight. A recent market study by Futron Corporation indicates that commercial space tourism could generate over $1 billion revenues by 2021 [2]. A good promotional campaign, with advertisements and publicity stunts like flying famous people into space, should increase the popularity of space tourism

6. CONCLUSION

For space tourism to open up as a visible commercial venture the most likely starting point will be from private aerospace development companies. In terms of investment in a space tourism start-up company, there is a gap between requirements of potential investors and the capability of companies to deliver them. Unconventional sources of financing may be required to overcome the difficulties of risk and payback period.

In summarizing the future visions of space tourism, we place no limits to our imaginations. Until the humanity's strong will to keep exploring and developing the technologies goes on, anything is possible. Nevertheless, we must face realities of the known understanding of the physics of the universe, monetary allocation to projects, political and societal will, and time. We live in an ambitious period; we are at a threshold of opening space for people who dream to see, hear, feel, taste, and experience what wonders the cosmos has to offer.

Space tourism will become a reality. The barriers that prevents Space Tourism is financing of development cost of new launch vehicles. Technologically, there are no major concerns in developing sub-orbital planes for Space Tourism.

Space Tourism can play a seminal role in future because it represents a huge market. More surveys and studies are required to determine the size of the market, but current studies indicate that Space Tourism can provide the necessary launch volume to achieve cheap access to space. For these reasons, governmental role in funding for development of new launch vehicles and providing a good, stringent legal framework for the industry becomes important.

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